Roe Herring Processing: Preservation and Factors Affecting Firming of Roe

J.W. Boyd, J. Cheng, Minh Dieu Huynh,
S.N. Williscroft and H. Tsuyuki

Technology Services Branch
Fisheries Management, Pacific Region
Department of Fisheries and Oceans
6640 N.W. Marine Drive
Vancouver, B.C. V6T 1X2
Canada

January 1980

Fisheries and Marine Service
Technical Report No. 921

Canadian Technical Report of Fisheries and Aquatic Sciences

These reports contain scientific and technical information that represents an important contribution to existing knowledge but which for some reason may not be appropriate for primary scientific (i.e. *Journal*) publication. Technical Reports are directed primarily towards a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries management, technology and development, ocean sciences, and aquatic environments relevant to Canada.

Technical Reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report will be abstracted in *Aquatic Sciences and Fisheries Abstracts* and will be indexed annually in the Department's index to scientific and technical publications.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Details on the availability of Technical Reports in hard copy may be obtained from the issuing establishment indicated on the front cover.

Rapport technique canadien des sciences halieutiques et aquatiques

Ces rapports contiennent des renseignements scientifiques et techniques qui constituent une contribution importante aux connaissances actuelles mais qui, pour une raison ou pour une autre, ne semblent pas appropriés pour la publication dans un journal scientifique. Il n'y a aucune restriction quant au sujet, de fait, la série reflète la vaste gamme des intérêts et des politiques du Ministère des Pêches et des Océans, notamment gestion des pêches, techniques et développement, sciences océaniques et environnements aquatiques, au Canada.

Les Rapports techniques peuvent être considérés comme des publications complètes. Le titre exact paraîtra au haut du résumé de chaque rapport, qui sera publié dans la revue *Aquatic Sciences and Fisheries Abstracts* et qui figurera dans l'index annuel des publications scientifiques et techniques du Ministère.

Les numéros 1-456 de cette série ont été publiés à titre de Rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457-714, à titre de Rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715-924 ont été publiés à titre de Rapports techniques du Service des pêches et de la mer, Ministère des Pêches et de l'Environnement. Le nom de la série a été modifié à partir du numéro 925.

La page couverture porte le nom de l'établissement auteur où l'on peut se procurer les rapports sous couverture cartonnée.

Fisheries and Marine Service

Technical Report No. 921

January 1980

ROE HERRING PROCESSSING: PRESERVATION AND FACTORS AFFECTING FIRMING OF ROE

by

J.W. Boyd, J. Cheng, Minh Dieu Huynh, S.N. Williscroft and H. Tsuyuki

Technology Services Branch

Fisheries Management, Pacific Region

Department of Fisheries and Oceans

6640 N.W. Marine Drive

Vancouver, B.C. V6T 1X2

This is the seventeenth Technical Report from the

Technology Services Branch

Vancouver

© Minister of Supply and Services Canada 1980

Cat. No. Fs 97-6/921 ISSN 0701-7626

TABLE OF CONTENTS

Page No.

ABSTRACT iv

RÉSUMÉ v

INTRODUCTION 1

MATERIALS AND METHODS 2

Source of Roe Herring - Trial A 2
- Trial B 3

Odor Evaluation 3

Assessment of Firmness 4

Analysis 4

RESULTS AND DISCUSSION 4

Odor Assessment 4

Firming Rates of Roe 5

Sorbic Acid Uptake and Residues 7

Salt Uptake 8

CONCLUSIONS 8

REFERENCES 9

TABLES 10-13

FIGURES 14-26

ABSTRACT

Boyd, J.W., J. Cheng, Minh Dieu Huynh, S.N. Williscroft, and H. Tsuyuki. 1980. Roe herring processing: preservation and factors affecting firming of roe. Fish. Mar. Serv. Tech. Rep. No. 921.

The efficacy of various preservatives in controlling the development of spoilage odors was evaluated during the period of time required in the 'aging' process to obtain reasonably firm roe from herring stored under different conditions. Potassium sorbate, formaldehyde, and chlortetracycline were reasonably effective in retarding the development of spoilage odors during storage of some sample lots of roe herring from different spawning areas. These preservatives have yet to be approved in Canada for use in the roe herring fishery.

The maximum concentration of sorbic acid in roe following storage of herring in sorbate solutions during the 'aging' process was 450 ppm which is well below the limits permitted in certain fish and food products in Canada. Processing of roe in brines reduced the sorbic acid level by at least 78%.

The firming rate of roe during the storage of whole herring is affected by salt concentration, temperature, post-mortem age of herring, and to a lesser extent, by the time of season and population differences. The rate increased with an increase in salt concentration (up to a certain level), and with an increase in temperature. In the absence of salt, roe from some sample lots of herring received acceptable firmness scores during the 'aging' process. However, fragility (loss of adhesion between eggs) was found to increase in the terminal product when herring had been stored in the absence of salt or in brines with low levels of salt during the 'aging' process.

Key words: aging, firming, herring, popping, preservatives, processing, rates, roe.

RÉSUMÉ

L'efficacité de préservateurs visant à éliminer les mauvaises odeurs a été évaluée dans différentes conditions, au cours du vieillissement que doit subir la rogue de hareng pour se raffermir. Le sorbate de potassium, le formaldéhyde et la chlortétracycline ont donné d'assez bons résultats avec des lots de harengs rogués de diverses provenances. L'emploi des préservateurs susmentionnés n'est pas encore permis au Canada, dans l'industrie du hareng rogué.

Au cours du vieillissement dans des solutions de sorbate, la teneur maximale en acide sorbique de la rogue s'est élevée à 450×10^{-6}, ce qui est bien au-dessous de la limite que le Canada autorise pour certains produits de la pêche et produits alimentaires. Le saumurage a réduit la teneur en acide sorbique d'au moins 78%.

La raffermissement de la rogue durant l'entreposage du hareng rogué dépend de la teneur en sel, de la température, du temps écoulé depuis la mort du poisson et, dans une moindre mesure, de l'époque où il a été pêché et des caractéristiques des stocks. La rogue s'est raffermie plus rapidement quand la tenur en sel (jusqu'à un certain point) et la température ont augmenté. Avec un vieillissement sans sel, le raffermissement de certains lots a été considéré comme acceptable. La friabilité de la rogue (perte de l'adhérence entre les oeufs) a cependant augmenté si le hareng n'avait pas séjourné dans le sel ou qu'on l'avait mis en saumure à faible teneur en sel.

Mots clés: vieillissement; raffermissement; hareng; rupture; préservateurs; vitesses; rogue.

INTRODUCTION

In Japan, herring roe which has been treated with sodium chloride (salt) during processing is considered a delicacy, and is referred to as kazunoko. From an economic standpoint kazunoko could also possibly be thought of as 'Pacific Gold', a luxury product, because of the high price paid by buyers in 1979 for the herring, and the resultant high price of the terminal product, kazunoko. During the 1979 roe herring season some buyers paid as high as $3,000 to $5,000 a ton for roe herring. The wholesale market price for Grade No. 1 roe in Japan has been as high as $32.00 per pound (December 3, 1979); in comparison the highest price during 1976 was $7.11 per pound. Imports of kazunoko by companies in Japan amounted to 7,107 metric tons (January - September, 1979) of which 4,932 metric tons were imported from Canada (Industry, Trade and Commerce).

The fishing industry of British Columbia has been exporting kazunoko, and some frozen whole herring to Japan for approxmately 8 years following the reopening of the herring fishery, for food purposes only, in the Pacific region.

The Pacific herring (Clupea pallasi), unlike the Atlantic species (Clupea harengus), spawns primarily above and just below the 0-tide line, depositing adhesive eggs primarily on marine vegetation such as rockweed and eelgrass; they spawn along the inshore areas of the coast beginning in February around the lower east coast of Vancouver Island (Area 18), at various times in other areas, and as late as June in Burke Channel (Area 8 B) (Webb, 1975).

During the spawning season, gillnet and seine boats harvest herring at a time when the roe is at the proper stage of ripeness (sexually mature from the standpoint of roe processing), and when the yield of roe from a test lot of combined male and female herring is at least 9% (by weight), preferably greater. Herring are transported to processing plants in the holds of fishing vessels without any preservative treatment, and on board some vessels in refrigerated sea water.

At the processing plants the majority of herring are stored in brines of varying strengths depending upon the processing practices within a plant, and the balance of the herring is frozen. Brining, or to a lesser extent freezing, of roe herring is necessary to change the texture of roe from soft to firm. Roe retrieved from fresh herring is excessively soft, which makes it difficult to retrieve the roe from the fish without causing damage. Following the brining process or the thawing of herring, the roe is extracted from the herring, immersed in dilute brines for washing, and then in saturated brine. 'Finished' roe is exported to Japan in saturated brine or dry salt; the temperature which is recommended for storage and transport of roe is -15°C.

Herring carcasses from roe herring operations are processed into meal at reduction plants. One problem which is of major concern to industry is the level of salt in meal and stickwater; the percent salt in meal and stickwater will vary with the concentration of brine used during the storage

of herring, and with the storage period. A salt content in herring meal greater than 5% is considered too high. Another less significant problem which occurs at times in plants during roe herring processing is the development of offensive spoilage odors. During roe herring processing "gibbers" (workers who extract roe from processed herring) work on processing lines for shifts of 10 to 12 hours, and find it difficult to work effectively in an environment of offensive odors.

Various preservatives have been used experimentally in fish preservation in an attempt to retard development of spoilage and offensive odors. One antimicrobial agent, sorbic acid, has been evaluated by investigators in experimental fish preservation trials. Sorbic acid is an unsaturated acid which can be utilized by mammals as a source of energy, with end products of carbon dioxide and water. At low concentrations sorbic acid is effective against molds, yeasts, and certain bacteria. It was found to be effective in inhibiting the development of the halophilic microorganism Sporendonema epizoum on salted fish (Boyd and Tarr, 1955). Nickerson and Starr (1960) developed a process for the preservation of fresh fillets, and light smoked or salted fish. The incorporation of sorbic acid in refrigerated sea water (RSW) was effective in retarding the development of spoilage odors during storage trials on herring, pollock, and mackerel (Karsti, 1971; Karsti and Gronmyr, 1973). Tomlinson et al. (1978) found during experiments on the storage of groundfish in RSW that the addition of sorbic acid (as K-salt) retarded the development of spoilage odors; the shelf life of fillets obtained from sorbic acid treated fish was extended about 4 days.

Food and Drug Regulations (Canada) permit the use of sorbic acid as a Class II preservative for many food items including smoked or salted dried fish; smoked or salted fish paste - level of use: 1,000 ppm. Although sorbic acid is classed as a Generally Recognized as Safe (GRAS) additive, regulations at present do not cover the use of sorbic acid as a preservative for fresh fish, fillets, and other fish products.

This report presents the results of separate trials which were carried out during two roe herring seasons (Trial A and B). The trials were undertaken to evaluate the efficacy of preservatives in retarding the development of offensive spoilage odors, and to assess the effect of salt, preservatives, and temperature on the 'firming' rate of roe during roe herring processing. Although various compounds were tested as potential preservatives in Trial A, the main purpose was to assess the efficacy of potassium sorbate.

MATERIALS AND METHODS

TRIAL A

Roe herring were obtained from gillnet boats operating in 2 different fishing areas. Three lots of herring from Long Harbour were early stock (caught February 20, March 1 and 11), and one lot from Burke Channel was late stock (caught June 1 and 3). Herring from gillnet boats in Burke

Channel were transferred to the charter boat Arctic Harvester for experimental processing and treatment. Approximately 1,700 kg of herring were used in these studies; the herring were manually sorted as to sex to eliminate the unnecessary labor involved in the handling of male herring during the storage trials.

Herring were immersed and stored in various solutions (Table 1) in 12 kg capacity plastic containers. During the Burke Channel test, 3 proteolytic enzymes (pepsin, pancreatin, and enzyme X108) were also used to ascertain whether the proteolytic activity of an enzyme would enhance the lysis of belly cavity tissue, and thus aid in the roe "popping" process. At the time of treatment the maximum post-mortem age of herring from the 2 areas was 8 hours. Herring samples from Long Harbour were stored at 8 C. Burke Channel samples were stored aboard the Arctic Harvester at ambient temperature (average temperature of solutions was 12 C) for 3 days, and then at 8 C in a laboratory cool room.

TRIAL B

The main objective of studies in this trial was to assess the effect of salt concentration, temperature, and some common preservatives on the 'firming' rate of roe. Herring were obtained from 3 different areas, (Long Harbour (caught February 21), Nanoose Bay (caught about February 23) and Puget Sound (caught April 25) to assess the effect of population differences on firming rates.

Herring were obtained from Long Harbour (early stock) at a time when most of the roe was ripe enough for processing. Fresh whole herring (post-mortem age 8 hr) were immersed in solutions containing 0, 3.7, and 11.0% salt with and without each of the following additives: sorbate 0.2%, formaldehyde 0.05% and chlorine dioxide 0.005%. Approximately 30 kg of herring were used per treatment. The samples were stored at 1 C and 10 C; the lower temperature of 1 C was selected to simulate the lowest ambient temperature short of freezing that might be encountered during the early part of the roe herring season, and the higher temperature was used to simulate ambient temperature conditions later in the season. The higher temperature studies were carried out in a precisely temperature controlled walk-in environment chamber.

Herring samples from Nanoose Bay without a known post-mortem history were stored at 1 C in solutions containing 0, 3.7, and 11% salt.

Herring were obtained during the latter part of April from a late spawning population in Puget Sound. The herring were stored at 1 C in solutions containing 0, 2.0, 3.7, 5.3, and 27% salt.

ODOR EVALUATION

The change in quality of roe herring during storage was assessed each day by a 3 member panel using a sensory score system (odor). Odor evaluation was made on herring samples without removing them from the preservative solutions. A 5 point sensory scale was used to assign odor

scores. When spoilage odors develop during sensory evaluation trials it is difficult to assign a meaningful score to samples at the lower part of the scale. However, for the purpose of this trial, preservation was considered to have ceased when a sample was assigned a 'mean' odor score of less than 2.5.

ASSESSMENT OF FIRMNESS

Firmness of unprocessed (roe extracted from herring) and processed roe was assessed by a sensory method (touch) and whenever possible by a mechanical method, Ottawa Texture Measuring System (OTMS) (Voisey, 1971). In Trial A roe samples were extracted from herring at intervals during the 'aging' process to determine the rate of firming. The firming rate of roe in Trial B was assessed by applying finger pressure to the belly cavity of each fish; in this trial the exact number of females in each sample was determined at the end of the experiment. The initial estimate of the number of females was assumed to be half of the total number of herring in a sample; immature females were also taken into consideration.

A 10-point scale was used to record the rate of firming of roe. A score of 5 was considered just adequate for the purpose of removing the roe from the fish. Roe with a score below 5 was too soft and fragile, and could not be 'popped' with ease from the fish.

To ascertain the firmness of roe samples with the OTMS, a flat surface circular puncture probe (area - 1 sq cm) was used. The force required to penetrate through a skein of a roe was recorded as kg/cm^2. To relate sensory and mechanical assessments, and for comparative purposes, the following information is given: unprocessed roe with an assigned sensory score of 5 was penetrated by the probe with a minimum force of 3.2 kg/cm^2, whereas in one trial a maximum force of 17.0 kg/cm^2 was required to penetrate processed roe.

ANALYSIS

Sorbic acid residue in processed and unprocessed roe, and in carcasses was determined by a rapid spectrophotmetric method (Maxstadt and Karasz, 1972). A slight modification of the method was used on samples with high levels of salt which was picked up by roe during processing; acidified homogenates prepared from such samples could not be filtered with No. 3 Whatman filter paper, presumably due to protein precipitation. Therefore samples were centrifuged at 12,000 g (15 min at 5 C) to obtain a clear supernatant. The amount of salt absorbed by carcasses during processing was determined by the "Quantab" method, and expressed as % of wet weight of herring. Six samples were used for each respective analysis.

RESULTS AND DISCUSSION

ODOR ASSESSMENT

The odor scores for herring samples (Trial A) during storage in solutions, and in the dry state are presented in Fig. 1. Off odors

developed at a faster rate in Burke Channel samples than in Long Harbour samples; this was probably due to the initial 3 days of slightly higher storage temperature (ambient) aboard the Arctic Harvester. Sorbic acid (0.1-0.2%), formaldehyde (0.08-0.2%), and chlortetracycline (0.001%) were effective in retarding the development of offensive odors. Formaldehyde controlled the development of spoilage odors during an experimental commercial roe herring trial (1974 - D. Petrie, B.C. Packers Ltd., personal communication). Herring stored in solutions containing the above additives were judged to be acceptable and assigned an odor score of 3 at 8 days, whereas fish held dry, in brine, and in water were assigned offensive scores of 2 or less. Although not shown in Fig. 1, samples stored in a 0.1% water solution of Fran-Kem (fumaric acid/sodium benzoate) were given an acceptable score of 4, equal to that of sorbate samples at day 6; an offensive odor score of 2 was given to comparable samples prepared with 3% salt solutions. The sodium of the salt probably enhanced the multiplication of some spoilage bacteria (marine forms) requiring sodium for growth and multiplication (MacLeod and Onofrey, 1956; Tomlinson and MacLeod, 1957). This sodium enhancing effect was also noted during the test on Long Harbour herring; herring were stored in water and 3% brine solutions containing 0.5% lactose to assess the odor inhibiting effect of a carbohydrate. The brine and water samples were scored 2 (offensive) and 3.5 (acceptable) respectively at day 6.

It was also of interest to note in one test that sorbic acid samples received the same acceptable score (3) at 6 days as fish stored in a 4% brine solution containing 10 ppm of the antibiotic chlortetracycline.

In Trial B in which the main objectives were to assess the effect of salt concentration, temperature, preservatives and herring populations on the firming rate of roe during the 'aging' process, it was found that formaldehyde (0.05%) at both 1 and 10 C was more effective in odor control than sorbate (0.2%) or chlorine dioxide (0.005%). At 10 C odor control was more critical than at 1 C. Formaldehyde was the only preservative exhibiting odor control over the 4 days duration of the experiment at the elevated temperature of 10 C.

Other preservatives such as benzoate alone, EDTA, metabisulfite and nitrite possess only limited effectiveness in the control of spoilage odor and bacterial growth during roe herring processing at 10 C (Tsuyuki and Williscroft, 1978). In the same study the effectiveness of formaldehyde on bacterial growth was beginning to show at a concentration of 0.01%. The use of this preservative at a concentration of 0.05% during roe herring preservation resulted in an increase of residual formaldehyde in the finished roe product of 4 - 6 ppm over the 10 - 12 ppm normally present in that prepared from untreated herring.

FIRMING RATES OF ROE

The firming rates of roe during storage of herring from Long Harbour and Burke Channel (Trial A) are presented in Figures 2 and 3 respectively. The rate was faster in Burke Channel samples than in Long Harbour samples. At 2 days a score of 5 or higher was assigned to 4 different treatments of Burke Channel samples whereas all scores were below 5 for Long Harbour

samples. The difference of 4 C between the initial storage temperatures (12 C and 8 C) as well as population differences could have been responsible for this variation in firming rate of roe. In Fig. 2 it may be noted that a score of 5 or higher was assigned only to samples which had been 'aged' in the presence of brine; similar results are evident in Fig. 3 with the exception of formaldehyde samples which were assigned a score slightly below 5 at 4 days. From the results obtained from tests in Trial A, it is evident that a concentration of at least 4% NaCl is required for the firming of roe during the 'aging' process. The firming rate of $CaCl_2$ brine stored samples was faster than that of any other treatment (Fig. 3); after 1 day of storage, roe samples received a score of 5. After 3 days the belly cavity walls of herring were lysed extensively, and the firm roe could be 'popped' with ease. However, the $CaCl_2$ solution was a green-brown in color, and very muddy in appearance. This discoloration was transferred to portions of the roe which were partly exposed due to the lysed belly cavities. The extreme lysis of the tissues was probably brought about by the enhancement of proteolytic enzyme activity by the calcium ion. Extreme lysis did not occur at this time of storage in any other samples of herring.

In Trial A the comparative firmness of a few unprocessed and processed roe was determined objectively with the use of an Ottawa Texture Measuring System (OTMS) (Table 2). A force of 3.31 kg/cm^2 was required to penetrate roe which had been assigned a sensory firmness score of 5-6 (Fig. 3, 9% brine at 4 days); following processing a force of 12.96 kg/cm^2 was required to penetrate the roe. A force of 1 to 2 kg/cm^2 was required to penetrate unprocessed roe samples which had received a sensory score of less than 5.

The firming rates of 'Long Harbour' roe (Trial B) during storage at 1 C of herring (early stock) in brines with and without added preservatives are presented in Figures 4, 5, 6, and 7; the numbers in brackets in the figures represent the percentage of roe with the same degree of firmness. A minimum of 70 female herring were examined per treatment.

At 1 C, roe did not firm over a 9 day period in the absence of salt. In each case, the firmness score reached 5 or higher more quickly with 11% salt than with the lower 3.7% salt. This level of firmness was reached in about 4 days with 11% salt while 1 to 2 days more were required with 3.7% salt. The effect of increasing salt concentration, up to a certain level, in enhancing the rate of firming is generally consistent with the results of Trial A.

At the higher storage temperature of 10 C the firming rates were faster (Figures 8, 9, 10, and 11). Even in the absence of salt a score of 5 was reached after 3 days. The higher levels of salt resulted in faster firming; about 1.5 days were required with 11% salt and a day longer with 3.7% salt.

The preservatives tested in Trial A and B did not have any significant effect on the firming rate of roe during the 'aging' process.

The effect of salt concentration on the firming rate of roe during storage (1 C) of herring which were collected from another area, Nanoose Bay, is shown in Fig. 12. The post-mortem history of the fish was not known with certainty, and could have been older than indicated by the supplier. In the absence of salt, a score of 5 was attained in 5 days; with 11 and 3.7% salt approximately 1.5 and 2.5 days were required respectively.

Compared to the Long Harbour 'brined' samples, the roe in these fish firmed 2 to 4 days sooner. This indicates that perhaps the post-mortem age of fish from Nanoose Bay was older than indicated or that the roe was at a stage of ripeness which may result in faster firming but which is difficult to resolve experimentally.

Fig. 13 shows the results of tests which were carried out to assess the effects of population difference (Puget Sound), time of season, and a wider range of salt concentration on the firming rate of roe during storage of herring at 1 C. In the absence of salt a score of 5 was attained in 6-7 days; the rate increased slightly with 2% salt. With 3.7 and 5.3% salt acceptable firming occurred in less than 3 days. Saturated brine increased the firming rate by approximately half a day.

Despite differences in firming rates of roe during storage of herring, which were collected from early, middle, and late spawning stocks, the direction of change with increasing salt concentrations is in general agreement. While a salt concentration of 3.7% appears to provide firming at a reasonable rate at 1 C, it is also pointed out that fragility (to be described in another communication) in the terminal product was found to increase at this lower salt level.

In Trial B it is of interest to note that in the absence of salt, firming of roe occurred during storage of Nanoose Bay and Puget Sound samples of herring at 1 C. However, at the same temperature, roe from Long Harbour samples did not firm during the 9 day period of the experiment but firmed at 10 C with some accompanying off odors. In Trial A, acceptable firming was not evident in any of the samples in the absence of salt before offensive odors developed, and the samples had to be discarded. In the absence of salt, roe did not become firm during storage of herring at sea at an average temperature of 8 C before spoilage occurred (Tomlinson et al., 1975). Firming was not attained in roe during storage of herring at 10 C before the samples had to be discarded because of spoilage odors (Boyd et al., 1972). From these variations in the firming rates of roe in different trials, it is suggested that some unknown minor variations in the stage of roe ripeness or the differences in stocks, or some other factors are responsible for the difference in results.

SORBIC ACID UPTAKE AND RESIDUES

The concentration of sorbic acid in carcasses and roe taken up during the 'aging' process, and the residual level in processed roe are recorded in Table 3. The concentration of sorbic acid in carcasses and unprocessed roe increased with an increase in storage time with the exception of roe samples from herring which had been stored 7 days in a 0.2% sorbic acid water

solution. The maximum levels of sorbic acid found in carcasses (655 ppm) and in unprocessed roe (450 ppm) are well below the limits permitted in certain fish and food products in Canada. Following processing of extracted roe in brines the levels of sorbic acid in roe were reduced a minimum of 78% and a maximum of 96.7%.

SALT UPTAKE

The highest level of salt in flesh plus skin was 3.69% following storage of whole herring in 14% brine for 7 days at 8 C (Table 4); in 9% brine the highest level was 2.85% after 5 days storage. Boyd et al. (1972) reported that after storage of roe herring in 10% brine for 4 days at 8 C the salt content was 3.3%. Tomlinson et al. (1975) found that the salt content of flesh rose to about 2.0% following 2 days storage of herring in 8% brine at 8 C; the salt content did not exceed 3% after 6 days storage.

For reduction purposes it is desirable to have a reasonably low level of salt in the carcasses.

CONCLUSIONS

Potassium sorbate (0.1 - 0.2%), chlortetracycline (0.001%), and formaldehyde (0.08 - 0.2%) were equally effective in delaying the onset of spoilage odors in Trial A during the storage of roe herring before extraction of the roe; fumaric acid plus sodium benzoate was also effective to a lesser degree. In Trial B (1 and 10 C) formaldehyde at a lower concentration of 0.05% was still effective for control of spoilage odor, but at 10 C sorbate (0.2%) and chlorine dioxide (0.005%) were not as effective as formaldehyde.

The uptake of sorbate by the flesh and roe during the storage of herring did not exceed a level of 655 ppm sorbic acid which is well below the level of 1,000 ppm permitted in certain foods. Sorbic acid has not been approved in Canada for use in the roe herring processing industry.

Salt concentration, temperature, post-mortem age of herring and, to a lesser extent, different herring populations and time of season all have a profound influence on the rate of firming of roe. Although roe from herring which are caught in certain areas (e.g. Trial B, Puget Sound samples) do become reasonably firm during the 'aging' process in the absence of salt, it is recommended that this method of processing not be used commercially as we have found that different stocks as well as those maturing at different times of the season, and successive yearly samples of the same stocks, not only display variable firming rates but also could lead to other deleterious effects on the terminal product such as fragility.

REFERENCES

Boyd, J.W., and H.L.A. Tarr. 1955. Inhibition of mold and yeast development in fish products. Food Technol. 9: 411.

Boyd, J.W., S.E. Geiger, and B.A. Southcott. 1972. Herring roe retrieval and processing. Fish. Res. Bd. Can. Tech. Rep. No. 336: 10 p.

Karsti, O. 1971. Storage experiments with mackerel in refrigerated sea water with potassium sorbate added. Fish. Res. Bd. of Can. Translation Series 2742: 12 p.

Karsti, O., and O. Gronmyr. 1973. Storage experiments with herring and small pollock in refrigerated sea water. The effect of additives CO_2 and K-sorbate. Fish. Res. Bd. of Can. Translation Series 2757: 18 p.

Maxstadt, J.J., and A.B. Karasz. 1972. Rapid spectrophotometric method for the determination of sorbic acid in fresh dairy products. J. of the A.O.A.C. 55:(1): 7-8.

MacLeod, R.A., and E. Onofrey. 1956. Nutrition and metabolism of marine bacteria. II. Observations on the relation of sea water to the growth of marine bacteria. J. Bact. 71: 661-667.

Nickerson, J.T.R., and L.D. Starr. 1960. United States Patent 2,933,399, April 19.

Tomlinson, N., G.A. Gibbard, S.E. Geiger, and E.G. Baker. 1975. Storage of roe herring at sea. Fish. Mar. Serv. Tech. Rep. No. 536: 16 p.

Tomlinson, N., S.E. Geiger, G.A. Gibbard, D.T. Smith, B.A. Southcott, and J.W. Boyd. 1978. Improving landed quality of groundfish by modification of refrigerated sea water. Fish. Mar. Serv. Tech. Rep. No. 783: 44 p.

Tomlinson, N., and R.A. MacLeod. 1957. Nutrition and metabolism of marine bacteria. IV. The participation of Na^+, K^+ and Mg^{++} salts in the oxidation of exogenous substrates by a marine bacterium. Can. J. Microbiol. 3: 627-638.

Tsuyuki, H., and S.N. Williscroft. 1978. The preservative values of formaldehyde and its content in roe and carcass before and after treatment of roe herring during processing. Fish. Mar. Serv. Tech. Rep. No. 821: 20 p.

Voisey, P.W. 1971. The Ottawa Texture Measuring System. J. Can. Inst. Fd. Technol. 4(3): 91-103.

Webb, L.A. 1975. The abundance of herring spawn in the coastal waters of British Columbia. Fish. Mar. Serv. Rep. Series No. PAC/T-75-28: 50 p.

TABLE 1

Concentration of additives in water and brine solutions used in storage trials on herring from Long Harbour and Burke Channel (Trial A).

Brine solutions	Additive (%)	Water solutions
-	0.05	sorbic acid
4% NaCl + sorbic acid *	0.10	sorbic acid
" + sorbic acid	0.20	sorbic acid
" + chlortetracycline	0.001	-
" + Fran-kem **	0.05	Fran-kem
-	0.08	formaldehyde
-	0.20	formaldehyde
4% NaCl + sorbic acid ascorbic acid	0.20 0.20	-
4% NaCl	-	-
8% "	-	-
9% "	-	-
14% "	-	-
4% $CaCl_2$	-	-
4% " + sorbic acid	0.20	-

* Potassium salt.

** Trade Mark - Washington Laboratories Inc., Seattle, Washington

Active Ingredients - Fumaric acid/Sodium benzoate

TABLE 2

Force (kg/cm^2) required to penetrate roe samples following storage of herring in brine solutions (unprocessed roe), and after processing the "extracted" roe with brines (processed roe).

Days stored	Roe	Brines: NaCl 4% + sorbate		Brines: NaCl 9%	
4	unprocessed	3.22*	(42)**	3.31	(38)
	processed	16.02	(15)	12.96	(19)
5	unprocessed	3.55	(21)	3.29	(28)
	processed	17.13	(20)	16.59	(20)

* Mean value.

** Number of replicates.

TABLE 3

Sorbic acid levels (ppm) in unprocessed and processed roe, and in carcasses following storage of whole herring in sorbic acid solutions.

Days stored	Sample	Percent sorbic acid* in solutions				
		Water			4% NaCl Brine	
		0	0.1	0.2	0.1	0.2
3	Roe	0	116.6	239.6	115.7	107.1
	Carcass	0	133.7	319.3	159.9	234.6
5	Roe	0	175.9	419.9	164.3	365.1
	Carcass	0	317.3	542.5	329.4	595.0
	Processed Roe	0		89.9	22.3	36.9
7	Roe		385.5	411.0		450.0
	Carcass		349.3	617.0		655.0
	Processed Roe		12.8	50.8		24.2

* Potassium salt.

TABLE 4

Sodium chloride levels (%) in herring following storage of whole herring in brines with and without added sorbate.

Test	Days stored	Strength of storage brines (%NaCl) 0	8	9	14	4 + sorbate
I	2	-	-	2.44	-	1.39 (43)*
	4	-	-	2.33	-	1.07 (54)
	5	-	-	2.85	-	1.48 (48)
II	2	-	-	1.95	-	1.13 (42)
	5	-	-	2.15	-	1.39 (35)
III	3	0.34	1.51	-	-	0.71 (52)
	5	0.36	1.49	-	-	1.10 (26)
	5	-	-	-	2.24	1.10 (51)
	7	0.37	2.08	-	-	0.98 (52)
	7	-	-	-	3.69	0.98 (73)

* Difference in NaCl levels (expressed as %) in herring samples following storage in brines containing low (4%) and high (8, 9, and 14%) concentrations of salt.

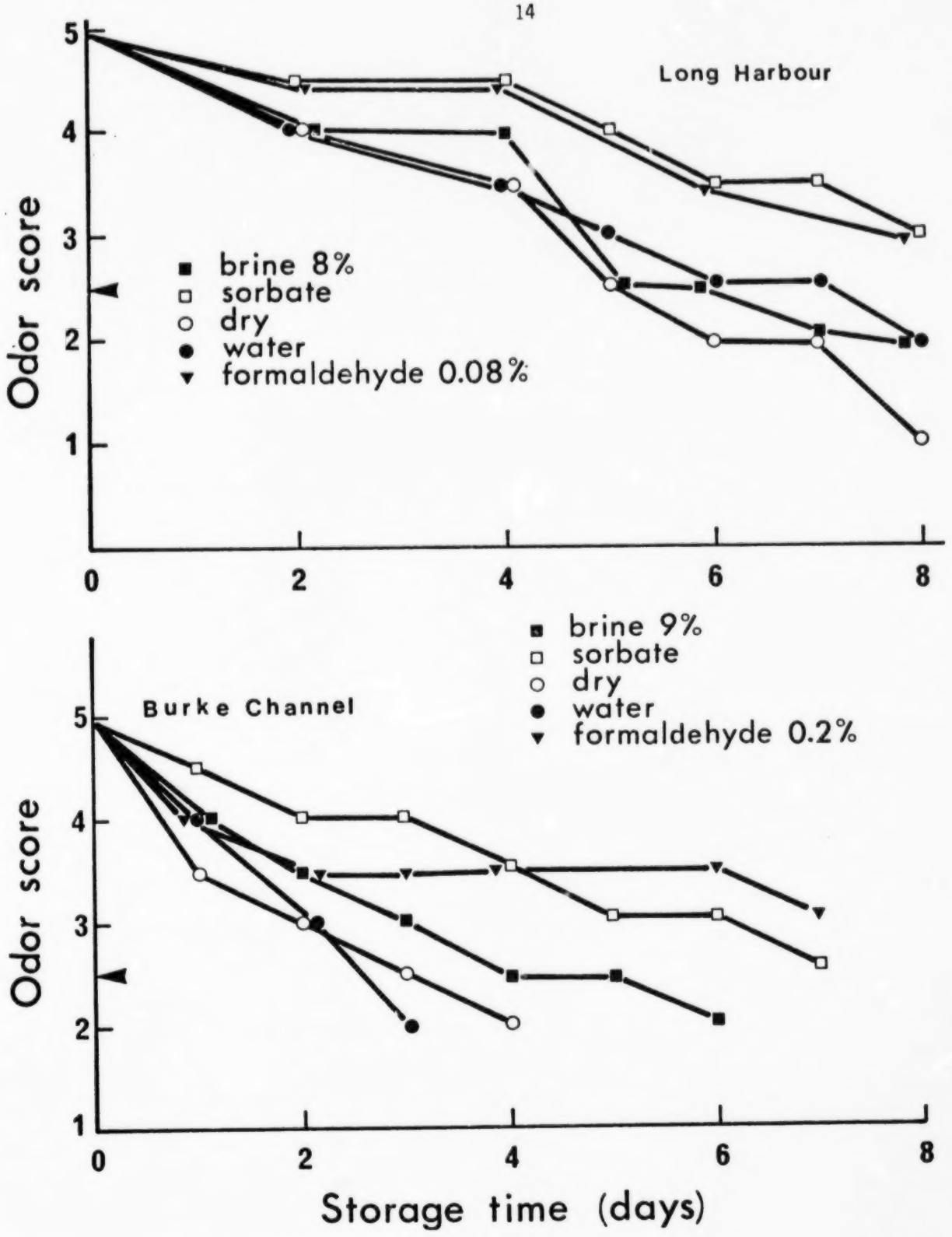

Fig. 1 Odor of herring samples (Trial A) during storage at temperatures of: Long Harbour samples - 8C; Burke Channel samples - 3 days at 12C, and then 4 days at 8C.

(◄) Odors were offensive below this 'mean' score.

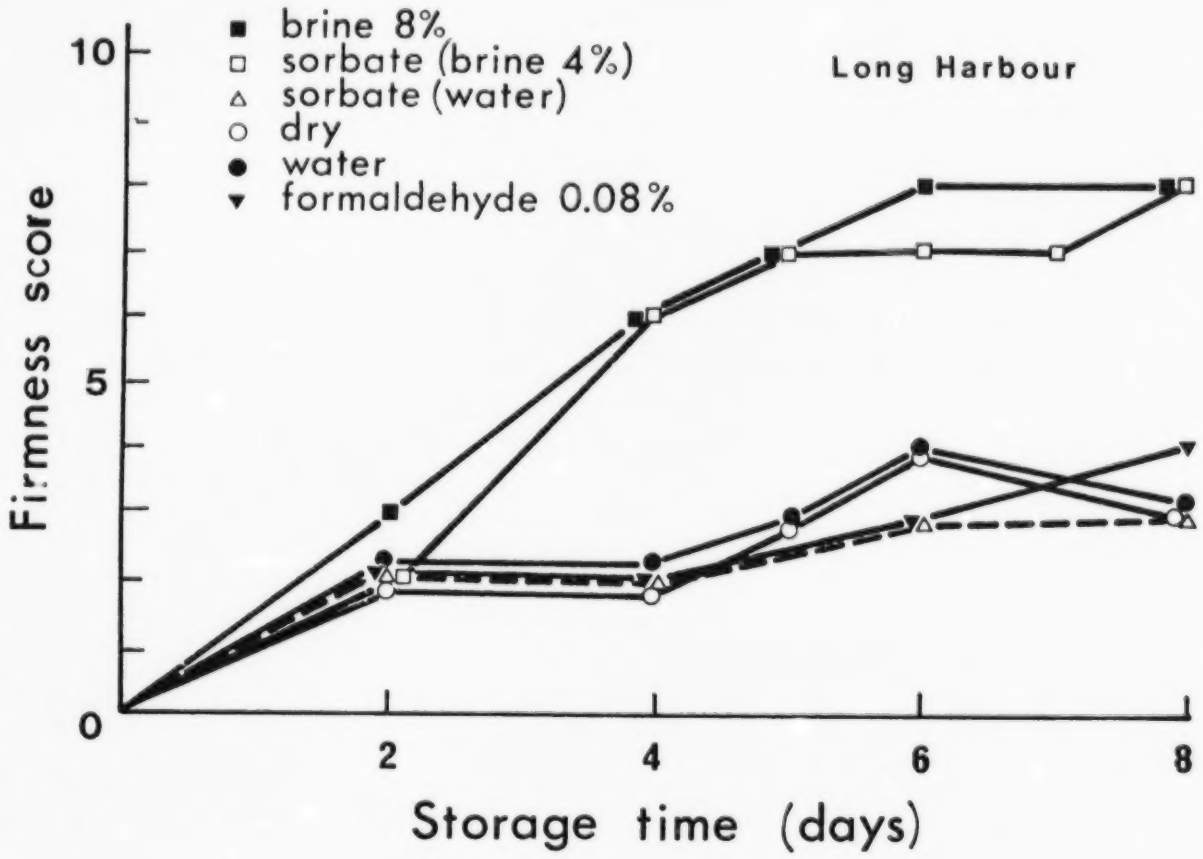

Fig. 2 Firming rate of unprocessed roe (Trial A) during storage of fish at 8C. Roe samples with a score of 5 and higher were suitable for 'popping'.

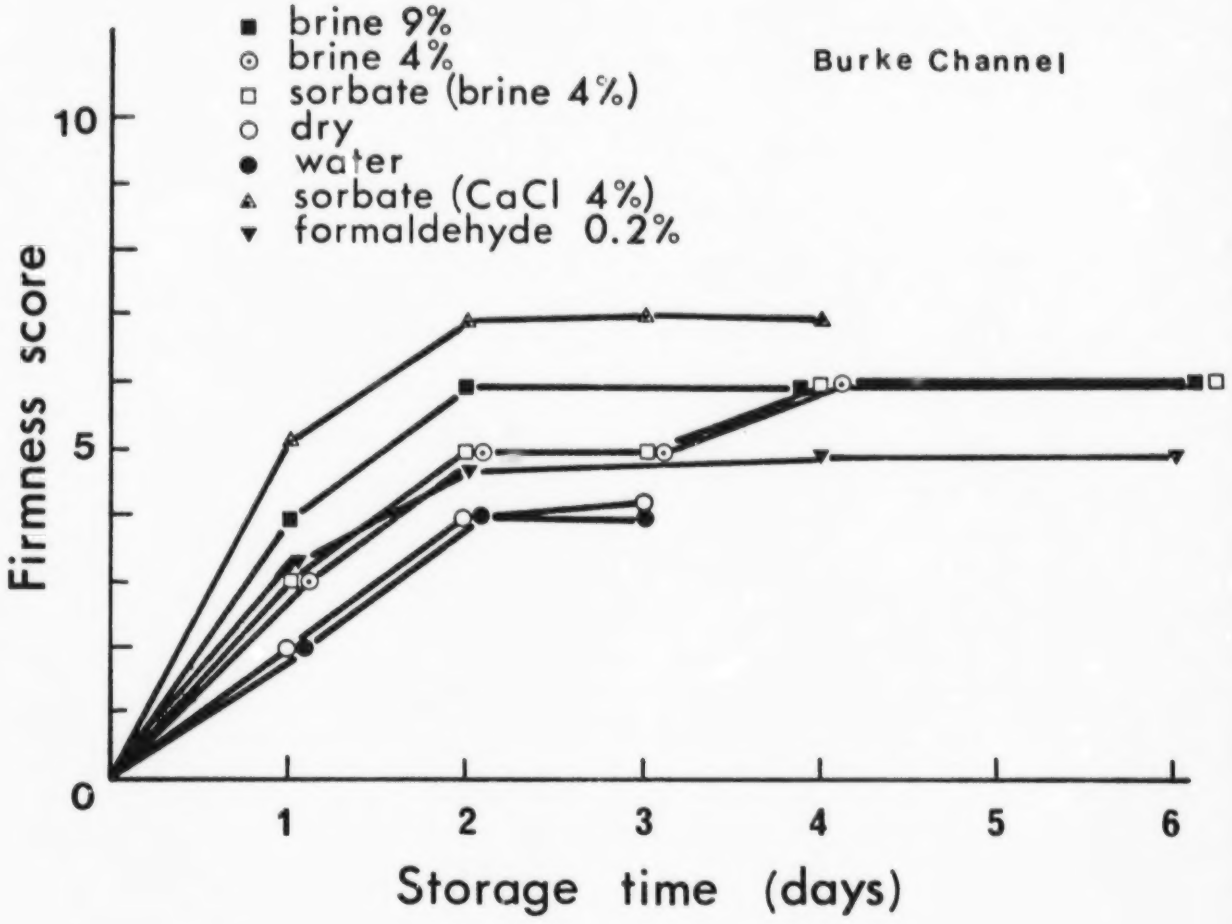

Fig. 3 Firming rate of unprocessed roe (Trial A) during storage of fish at 12C for 3 days, and then at 8C for 3 days. Roe samples with a score of 5 and higher were suitable for 'popping'.

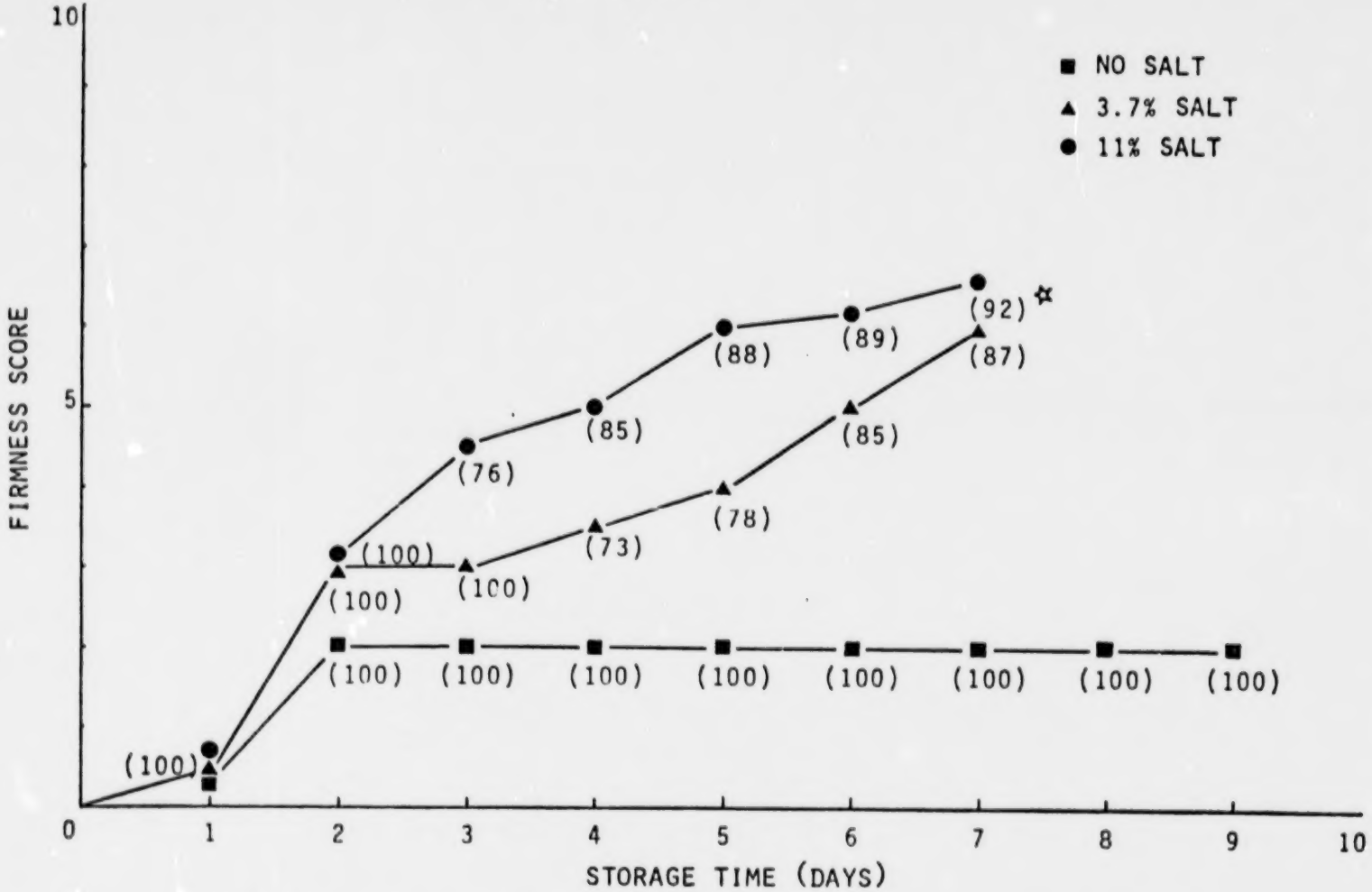

FIG. 4. FIRMING RATE OF ROE (TRIAL B, LONG HARBOUR) DURING STORAGE OF HERRING AT 1C. CONTROL - NO PRESERVATIVE.

☆ IN FIGURES 4 TO 13 THE NUMBERS IN BRACKETS REPRESENT THE PERCENTAGE OF ROE WITH THE SAME DEGREE OF FIRMNESS; A MINIMUM OF 70 FEMALE HERRING WERE EXAMINED PER TREATMENT.

EFFECT OF SALT CONCENTRATION AND PRESERVATIVE ON THE FIRMNESS OF ROE AT 1° C

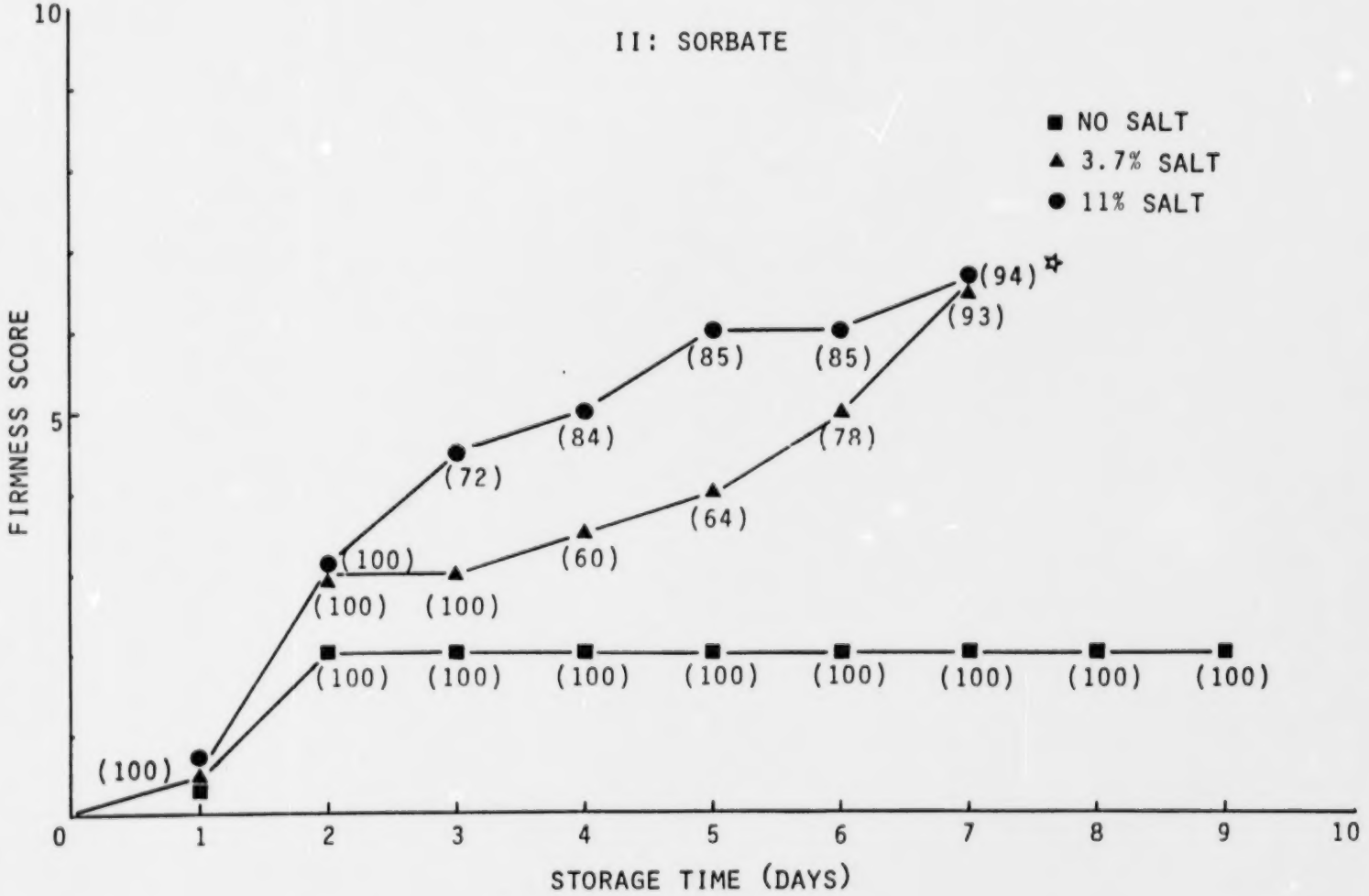

FIG. 5. TRIAL B, LONG HARBOUR HERRING

☆ PERCENTAGE - SEE FIG. 4.

EFFECT OF SALT CONCENTRATION AND PRESERVATIVE ON THE FIRMNESS OF ROE AT 1° C

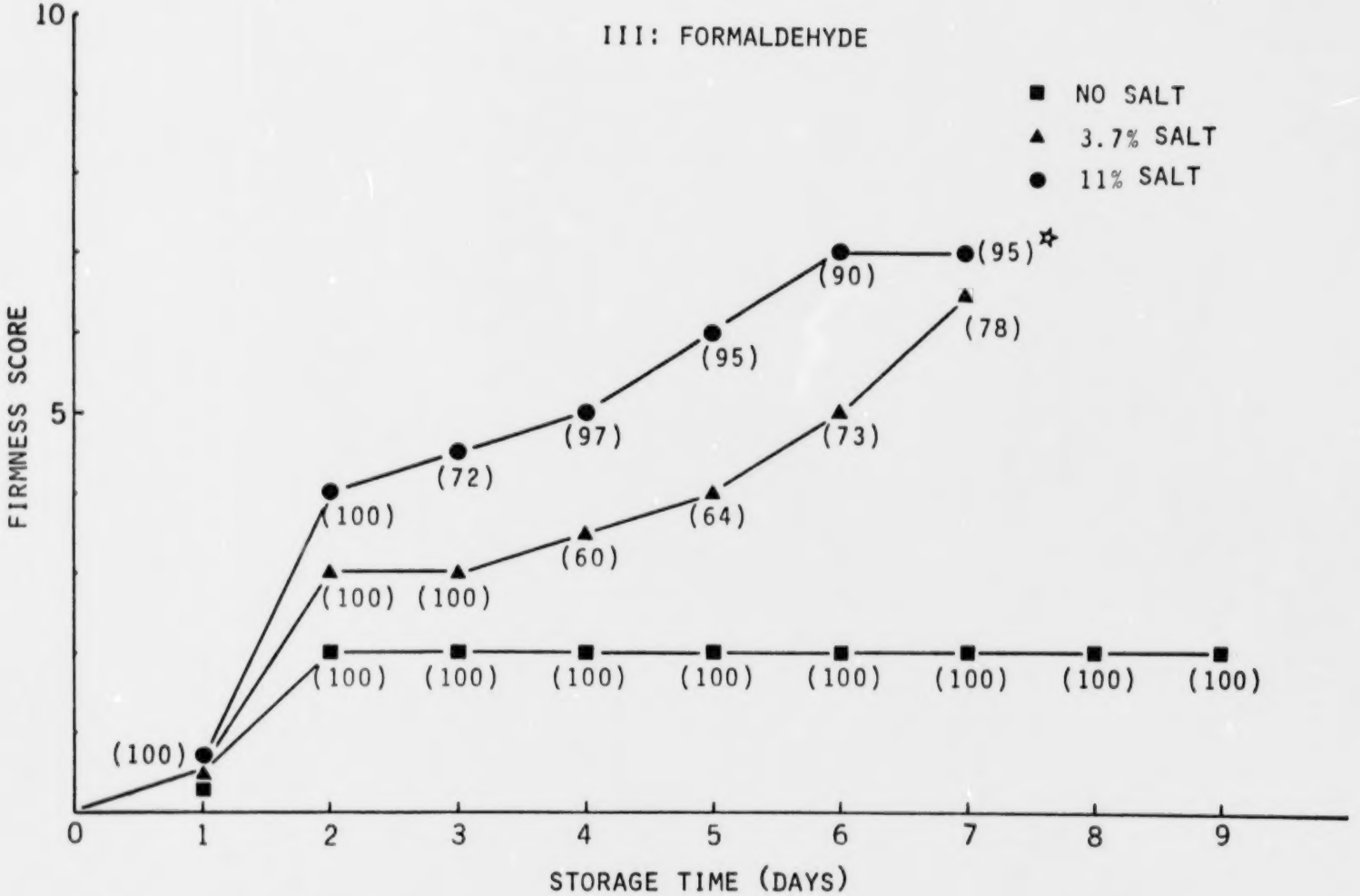

FIG. 6. TRIAL B, LONG HARBOUR HERRING

☆ PERCENTAGE - SEE FIG. 4.

EFFECT OF SALT CONCENTRATION AND PRESERVATIVE ON THE FIRMNESS OF ROE AT 1° C

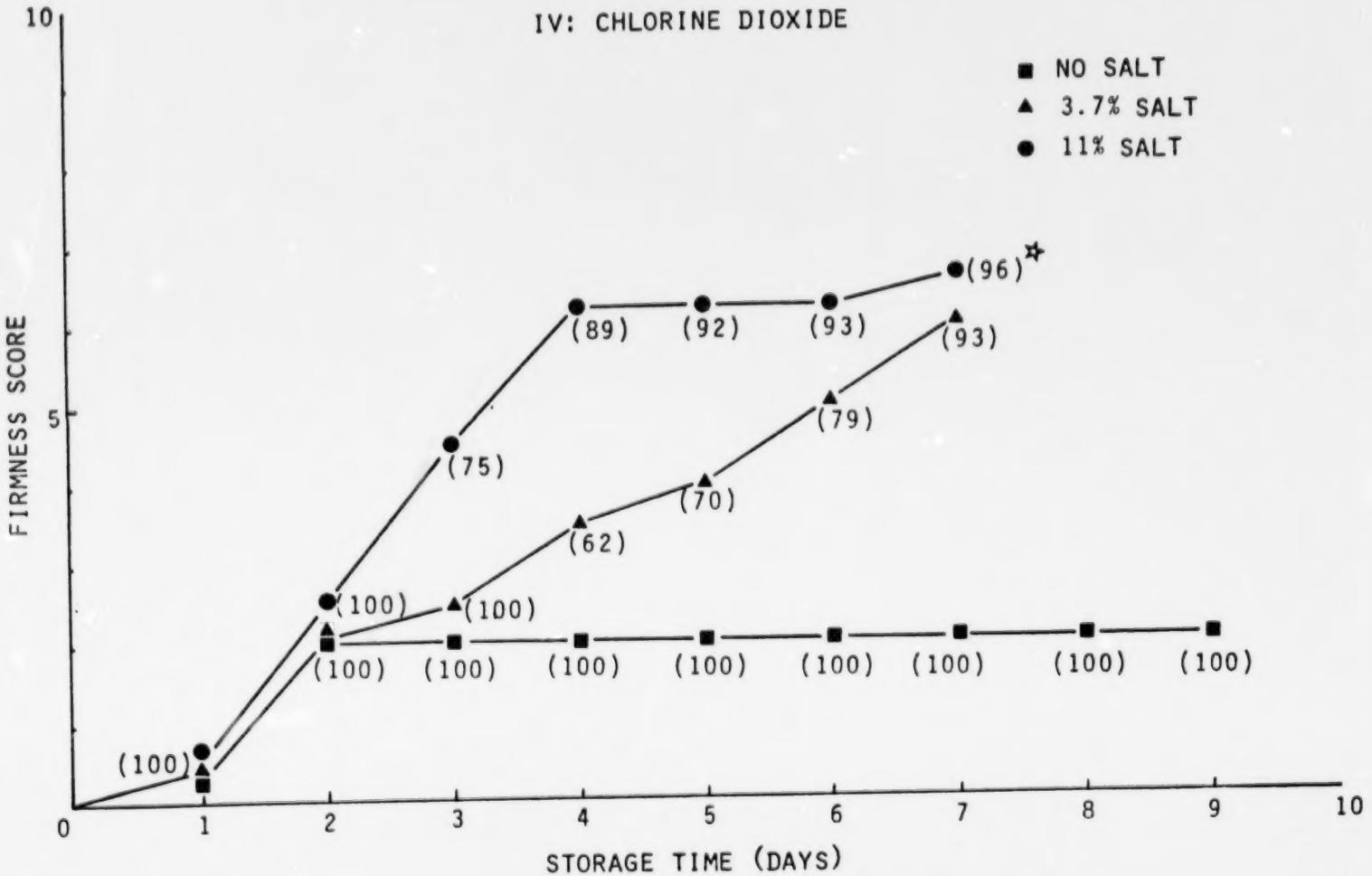

FIG. 7. TRIAL B, LONG HARBOUR HERRING.

✡ PERCENTAGE - SEE FIG. 4.

EFFECT OF SALT CONCENTRATION AND PRESERVATIVE ON THE FIRMNESS OF ROE AT 10° C

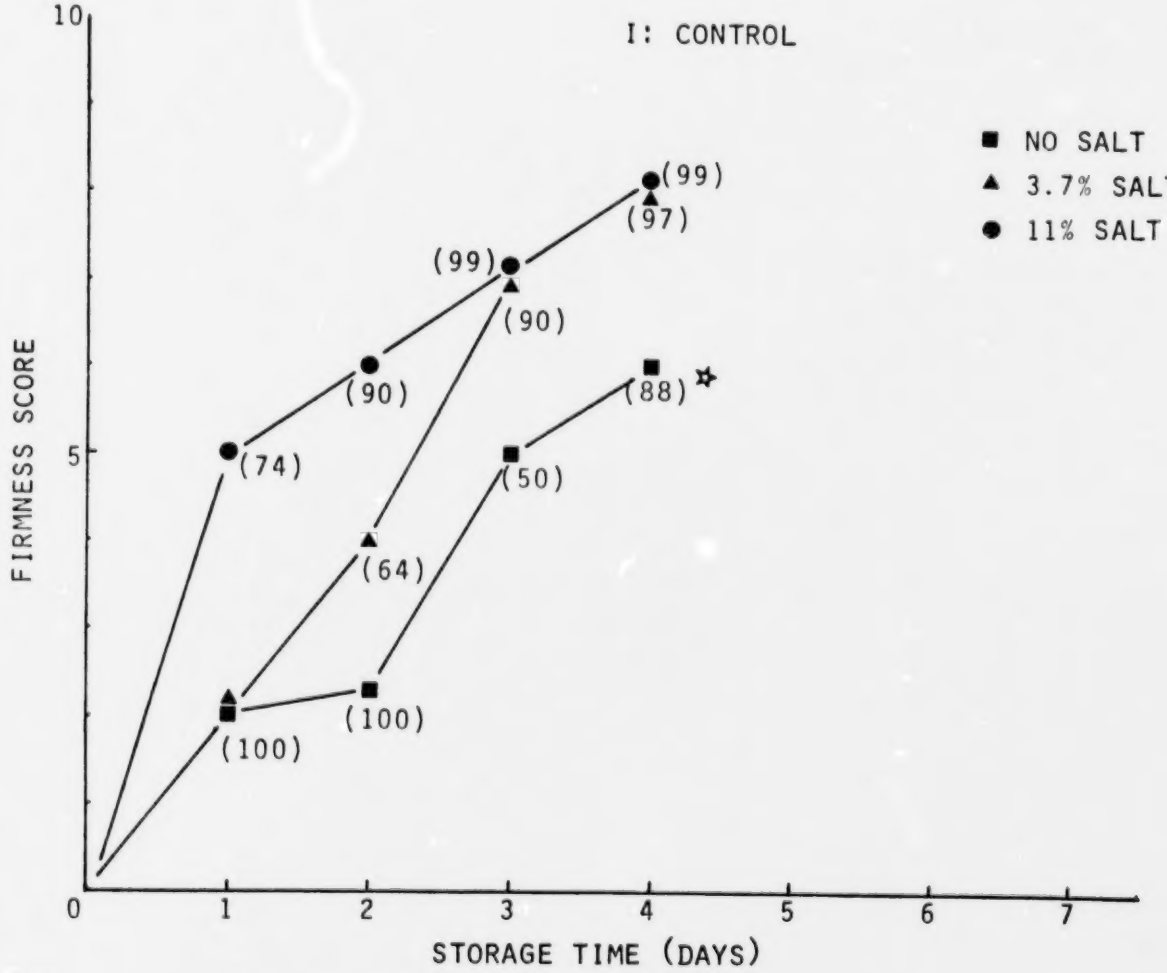

FIG. 8. TRIAL B, LONG HARBOUR HERRING.

✡ PERCENTAGE - SEE FIG. 4.

EFFECT OF SALT CONCENTRATION AND PRESERVATIVE ON THE FIRMNESS OF ROE AT 10° C

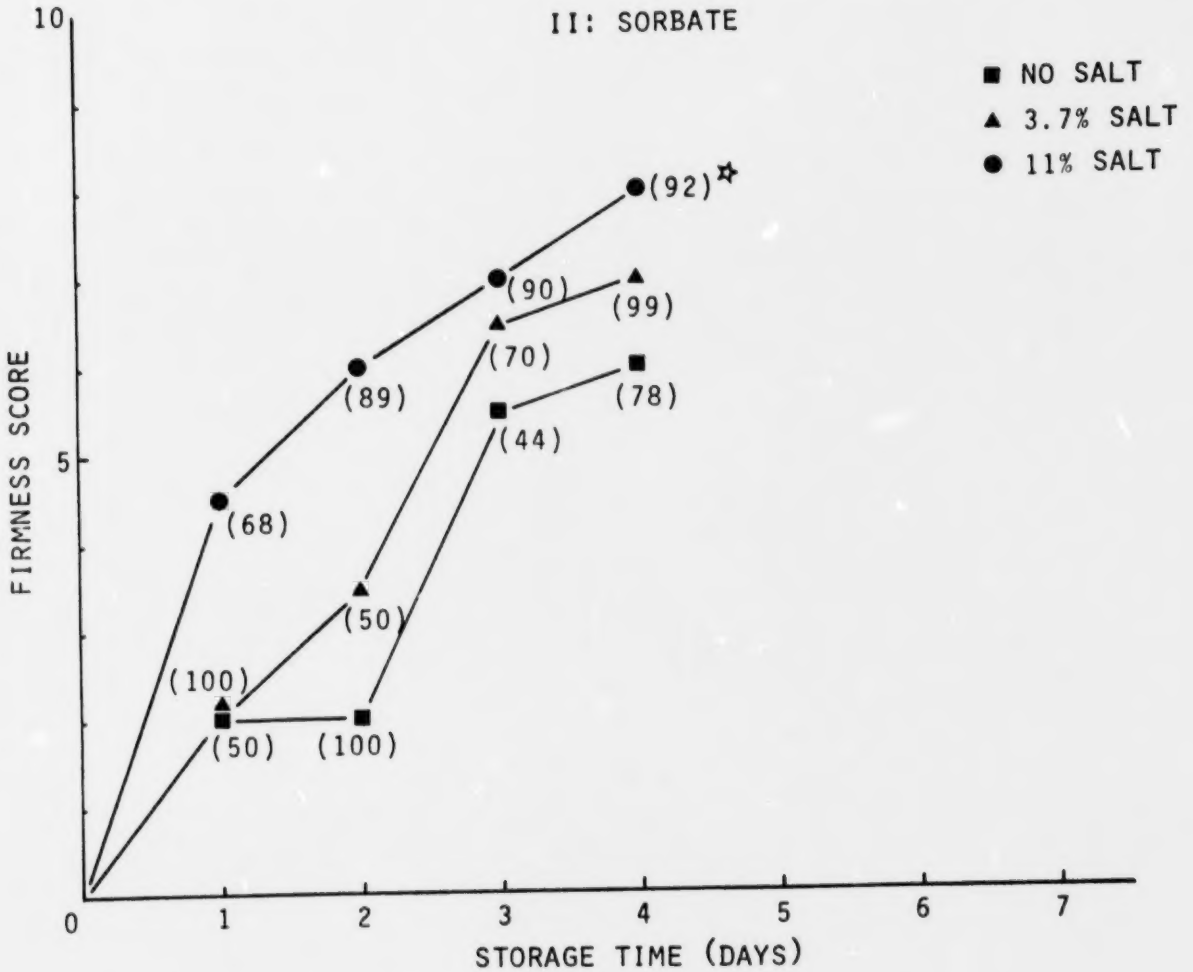

FIG. 9. TRIAL B, LONG HARBOUR HERRING.

☆PERCENTAGE - SEE FIG. 4.

EFFECT OF SALT CONCENTRATION AND PRESERVATIVE ON THE FIRMNESS OF ROE AT 10° C

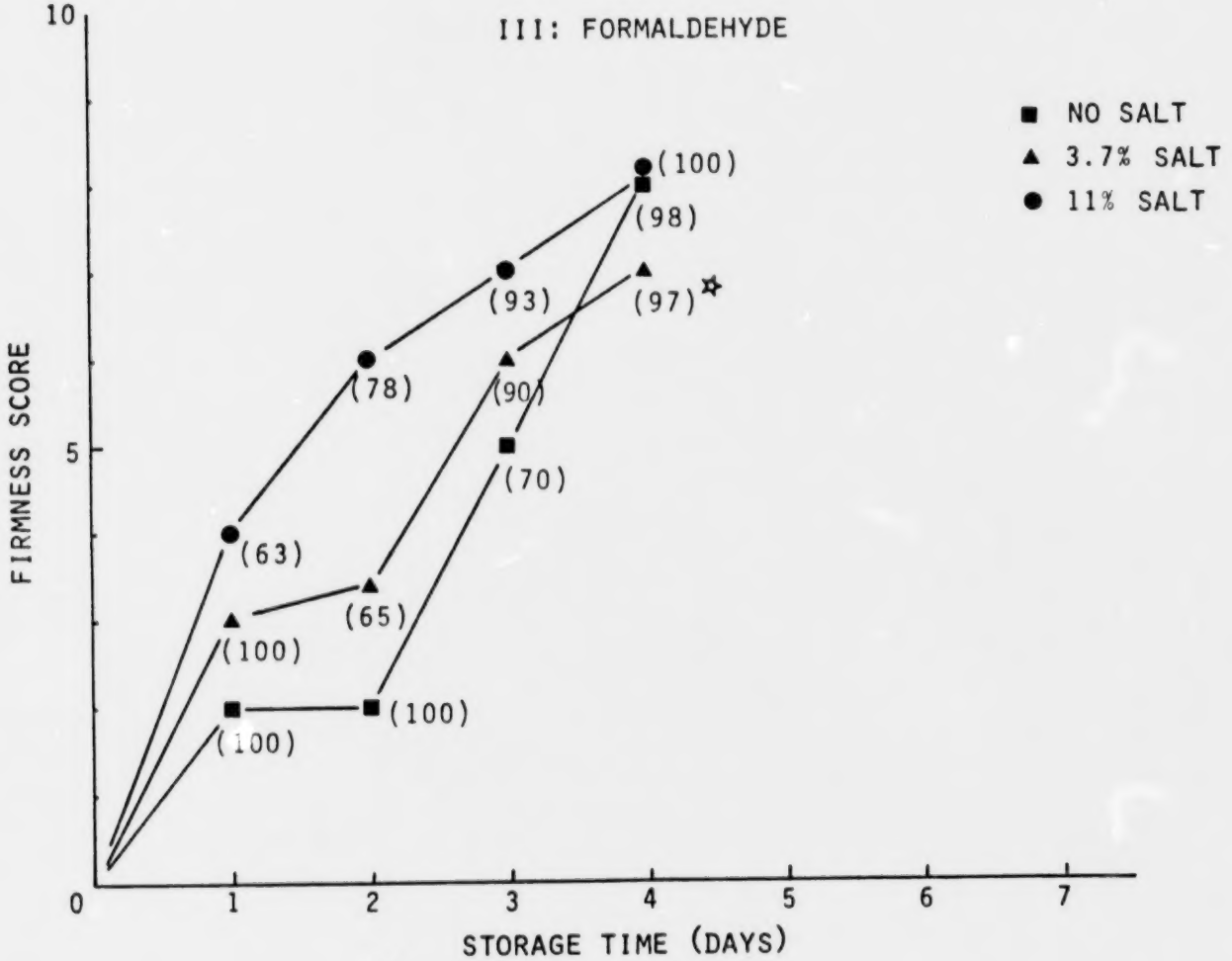

FIG. 10. TRIAL B, LONG HARBOUR HERRING.

✡ PERCENTAGE - SEE FIG. 4.

EFFECT OF SALT CONCENTRATION AND PRESERVATIVE ON THE FIRMNESS OF ROE AT 10° C

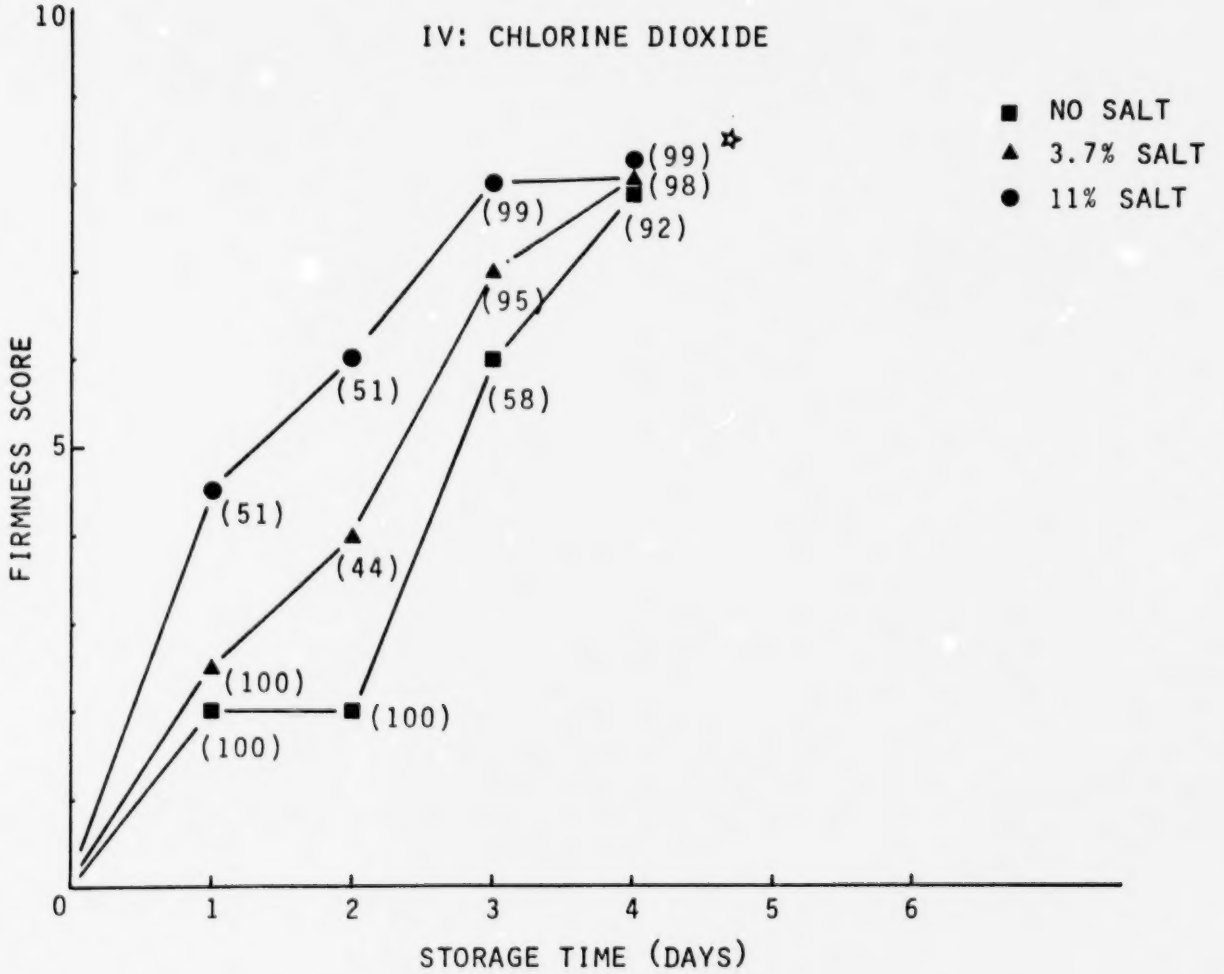

FIG. 11. TRIAL B, LONG HARBOUR HERRING.

✡PERCENTAGE - SEE FIG. 4.

EFFECT OF SALT CONCENTRATION ON THE FIRMNESS OF ROE AT 1° C

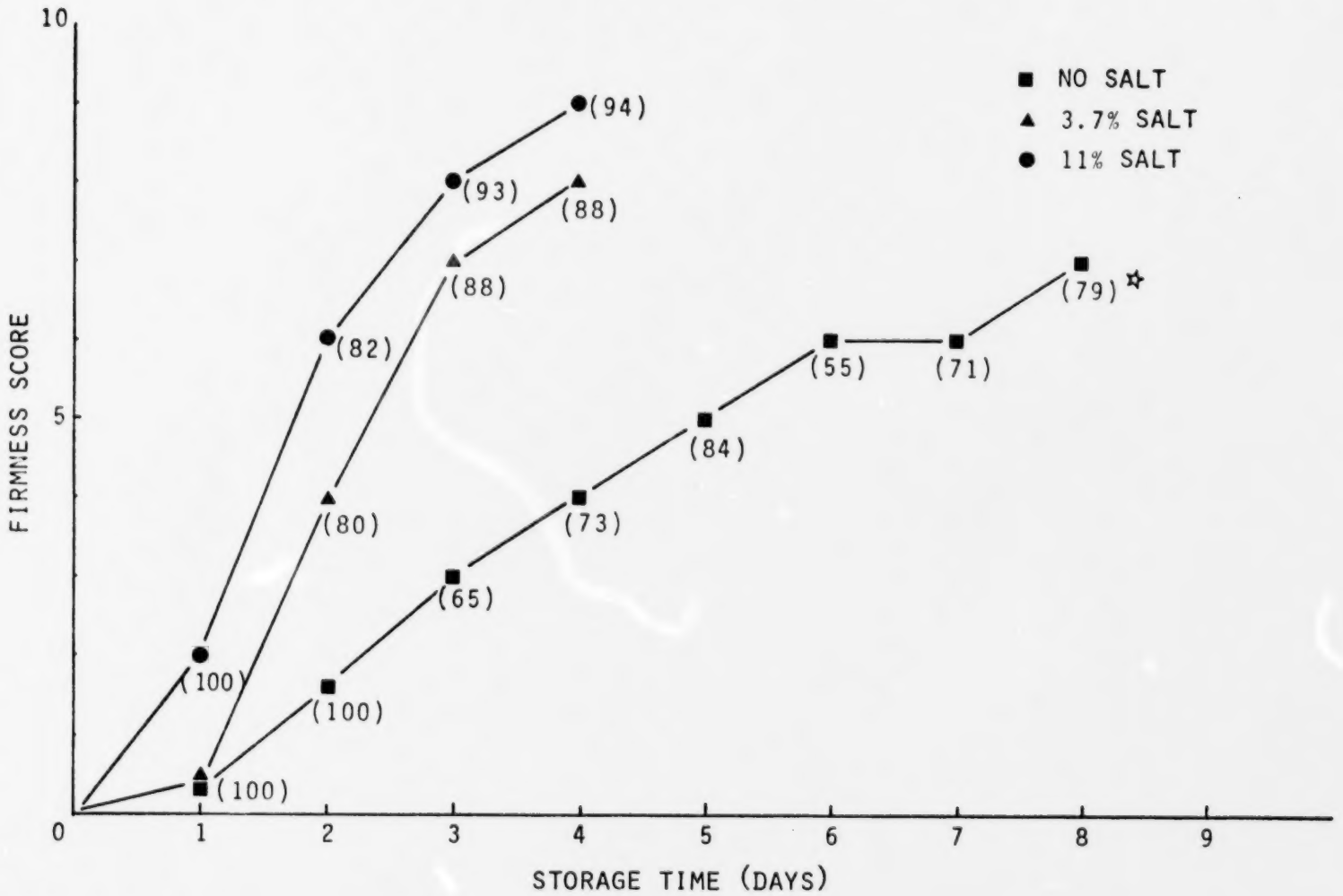

FIG. 12. TRIAL B, NANOOSE BAY HERRING.

✡ PERCENTAGE - SEE FIG. 4.

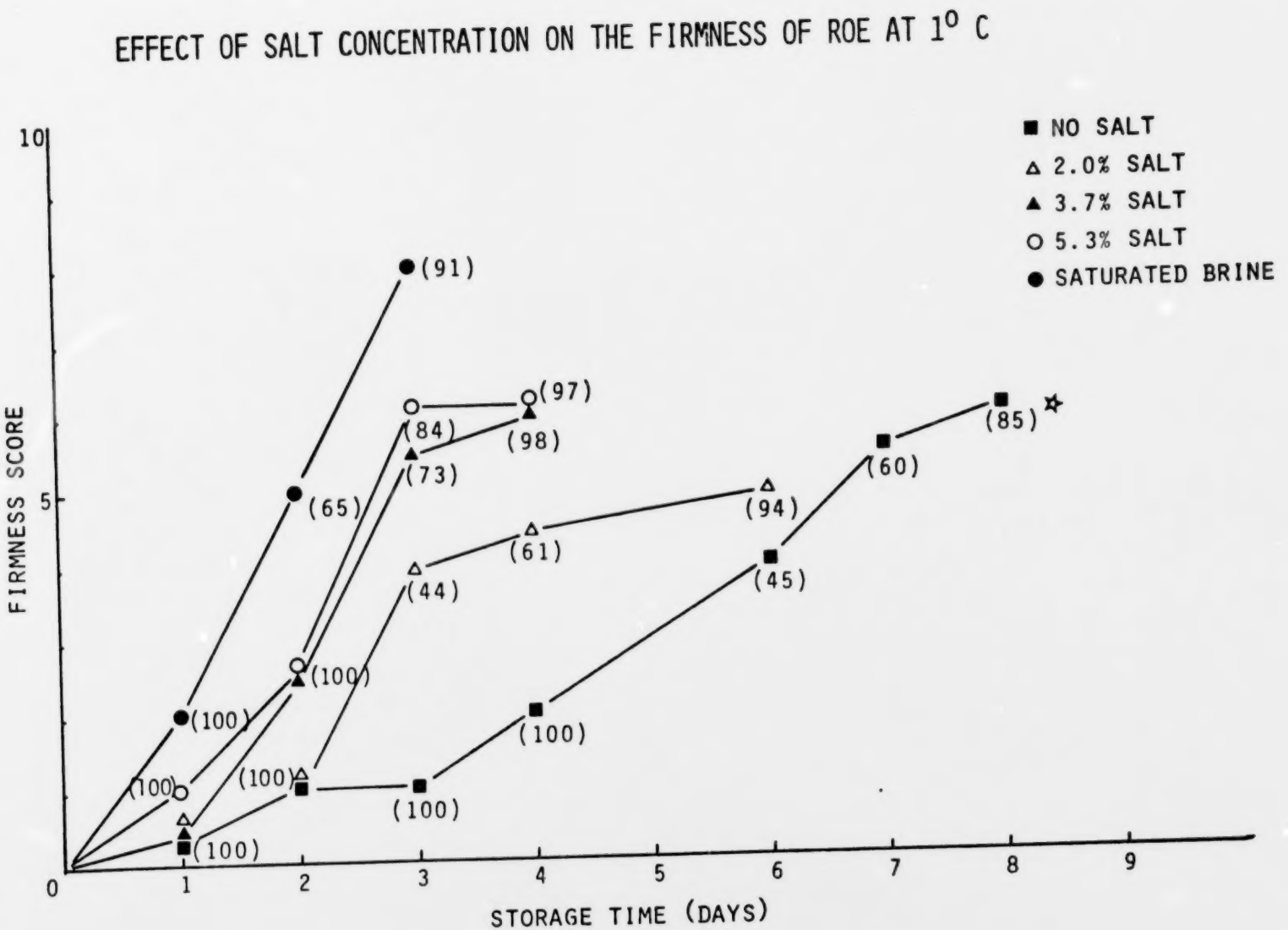

FIG. 13. TRIAL B, PUGET SOUND HERRING.

☆ PERCENTAGE - SEE FIG. 4.